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## Testing, development and demonstration of large scale solar district heating systems

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### Abstract

In 2013-2014 the project “Testing, development and demonstration of large scale solar district heating systems” was carried out within the Sino-Danish Renewable Energy Development Programme, the so called RED programme jointly developed by the Chinese and Danish governments. In the project Danish know how on solar heating plants and solar heating test technology have been transferred from Denmark to China, large solar heating systems have been promoted in China, test capabilities on solar collectors and large scale solar heating systems have been improved in China and Danish-Chinese cooperation on solar heating has been improved.

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### 1. Introduction

Denmark is the frontrunner Worldwide on large solar heating plants connected to district heating systems, [1]. By the end of 2013, 9 of the 10 largest European solar heating plants were in operation in Denmark [2], and the total solar collector area of Danish solar heating plants was about 386,000 m<sup>2</sup>. 37 solar heating plants with collector areas higher than 5000 m<sup>2</sup> were in operation in Europe and out of these systems, 30 were in operation in Denmark. It is expected that by the end of 2014 the 10 largest solar heating plants in Europe will be in operation in Denmark, and that the total solar collector area in Danish solar heating plants will be increased to about 566,000 m<sup>2</sup> [3]. It is also expected that the strong growth in Denmark in this field will continue in the coming years. There are many reasons for the strong growth of solar heating plants in Denmark:

- Denmark has a lot of district heating, about 63% of all Danish homes are connected to district heating systems
- Low temperature levels are used in the district heating systems. A typical forward temperature to towns is about 80°C and a typical return temperature from towns is about 40°C
- Denmark has ambitious climate goals. By 2030 the total heat demand of the country must be covered by renewable energy sources, by 2035 no fossil fuel must be used for heat and electricity and by 2050 Denmark must be fossil fuel free
- Denmark has a decentralized energy supply system and a high share of wind energy for electricity production. In the first half of 2014, 41% of the Danish electricity consumption was produced by wind turbines. By 2020, 50% of the Danish electricity consumption must be produced by wind turbines
- There are high taxes on fossil fuels. Typical tax is about 0.035 euro per kWh produced heat
- During the last 10 years a strong development of the large flat plate solar collectors used for solar heating plants has been achieved, both with regard to efficiency, costs and durability. A life time of about 30 years for marketed solar collectors is estimated, [4], [5]
- Simple, well proven and reliable technology
- No involvement of installers
- Good cooperation between solar heating plant owners. Regular meetings with exchange of know how and experience
- The experience from the early installed large Danish solar heating plants are good, both with regard to thermal performance in practice and reliability, [3]
- The costs for solar collector fields with marketed solar collectors installed on the ground and ground costs are relatively low
- Ongoing efforts to further develop solar collectors and solar collector fields
- Ongoing efforts to develop and demonstrate seasonal heat storage and to integrate solar heating plants into the energy system, [6]

The project “Testing, development and demonstration of large scale solar district heating systems” was started in March 2013 with the following aims:

- to transfer Danish know how on solar heating plants and solar heating test technology to China
- to promote large solar heating systems in China
- to improve test capabilities on solar collectors and large scale solar heating systems in China
- to promote Danish-Chinese cooperation on solar heating.

The project, which will be finished in October 2014, is carried out within the Sino-Danish Renewable Energy Development Programme, the so called RED programme jointly developed by the Chinese and Danish governments. The participants of the project are:

- China Academy of Building Research, China (CABR)
- Beijing Solar Energy research Group Co. Ltd, China (BSERI)
- Sunda Solar energy Technology Co. Ltd, China (Sunda)
- Institute of Electric Engineering, Chinese Academy of Sciences, China (CAS IEE)
- PlanEnergi, Denmark
- Department of Civil Engineering, Technical University of Denmark, Denmark (DTU)

## 2. Project activities

The project consists of the following activities:

- Solar collector test methods have been developed by DTU, CAS IEE and CABR
- Solar collector test facilities at CABR and CAS IEE have been improved

- Solar collector tests have been carried out at CABR and CAS IEE using different test methods
- Solar collector test results have been analysed by DTU
- A TRNSYS simulation model for a solar collector field has been developed and validated by means of measurements from a Danish solar heating plant by DTU
- Four large scale demonstration solar heating systems in China have been designed, constructed and started up by PlanEnergi and Sunda
- Several project meetings have been carried out both in China and in Denmark
- The Chinese partners have visited several large Danish solar heating plants
- Project results have been presented at workshops in China with solar industry participation
- Analyses of measurements from the large demonstration solar heating systems in China by DTU, BSERI and Sunda
- Validation of the developed TRNSYS simulation model by means of measurements from one of the large Chinese demonstration solar heating systems
- Compilation of handbooks on large solar heating plants by CABR, DTU and PlanEnergi

The project results are described in reports, which are prepared both in English and in Chinese.

A new dynamic test method for solar collectors has been developed and compared to the Quasi-Dynamic Test (QDT) test method, [7], [8]. The advantage of this method is that solar collectors can be tested outdoor much faster than by means of the traditional steady state test method, since even strongly variable weather conditions are suitable for the new method.

Test facilities for solar collectors have been improved at CABR and CAS IEE in such a way, that solar collectors in the future can be tested at high temperature levels and that large solar collector panels can be tested. Fig. 1 shows a photo of the solar collector test facility at CABR, [9].



Fig.1. Solar collector test facility at CABR.

Both a flat plate solar collector and an evacuated tubular solar collector have been tested at CABR and CAS IEE using both the steady state test method and the new developed dynamic test method. The test results have been analysed by DTU, [10]. The investigations showed that the new dynamic test method can be used to determine the

efficiency curves for both the flat plate solar collector and the evacuated tubular solar collector. However, the solar collector efficiency curves for the two tested solar collectors determined by the two methods are somewhat different. In this connection it must be mentioned that efficiencies are measured in different test facilities. The differences are therefore not only caused by the different test methods, but also by the different test facilities inclusive monitoring systems. It is recommended to further improve the new dynamic test method and to test the method for a complete solar collector field with the aim to determine the collector efficiency for the solar collectors used in the solar collector field. The new method is most likely especially suitable for this purpose.

A TRNSYS simulation model for a typical Danish solar collector field with large solar collector panels placed on the ground has been developed. The collector field consists of a number of parallel connected rows with a number of serial connected solar collector panels. The model was validated by means of measurements from Brødstrup solar heating plant, [11].

Four large scale demonstration solar heating systems in China have been designed, constructed and started up. The solar heating systems are only for domestic hot water supply and the solar collector fields are based on a high number of relatively small evacuated tubular solar collectors placed on roofs, see Fig. 2. The technology used in the Chinese systems is completely different from the technology used in the Danish solar heating plants where a high number of large flat plate solar collector panels are installed on the ground, see Fig. 3.



Fig. 2. Part of solar collector field for Shahe campus of the Central University of Finance and Economics.



Fig. 3. Dronninglund solar heating plant with a solar collector area of 37573 m<sup>2</sup>.

Several project meetings have been carried out, both in China and in Denmark. Project results have been presented at workshops in China with participants from the Chinese solar industry. The Chinese partners of the project have visited several large Danish solar heating plants, see Fig. 4.



Fig. 4. Visit at Helsingør solar heating plant during a study tour to Danish solar heating plants.



Reports on analyses of measurements from Chinese demonstration systems and on validation of the TRNSYS simulation model by means of measurements from a Chinese demonstration system as well as the handbook on large solar heating plants have been worked out, [12], [13].

### 3. Conclusions

The Danish/Chinese project “Testing, development and demonstration of large scale solar district heating systems” has transferred Danish know how on solar heating plants and solar heating test technology to China, has improved the test capabilities on solar collectors and large scale solar heating systems in China, has developed a new dynamic test method for solar collectors and solar collector fields, which can speed up outdoor tests of solar collectors and solar collector fields.

All in all, the project has improved the Danish-Chinese cooperation on solar heating.

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